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The Characteristics and Porosity Determination of Carbonate rock (Pila Spi formation), Bekhair anticline, Zakho, Kurdistan Region of Iraq

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ABSTRACT: The main idea of this work is to determine the characteristics and porosity of Pila spi Formation (carbonate rock) at the Bekhair anticline, Gully of Zakho, Zakho, Kurdistan Region, Iraq. In order to be able to consider the Formation has ability holding a reasonable amount of hydrocarbon that can be occupied in pore spaces of the Formation in this section. Because Porosity is a measure of the capacity of reservoir rocks to contain or store fluids. The fluids stored in the pore spaces within the reservoir rocks could be gas, oil, and water. The high porosity values indicate high capacities of the reservoir rocks to contain these fluids, while the low porosity values indicate the opposite.

The porosity results of the Pila Spi Formation indicating dolomitization and leaching enhance the secondary porosity of moldic, vuggy and inter-crystalline pore spaces of the fine crystalline dolostone. These results are revealing as good porosity, and had been enhanced by some diagenetic processes, especially dolomitization and dissolution, and later followed by secondary effects from tectonics activities.

I.INTRODUCTION

The Pila Spi Formation is one of the prominent formations forming continuous ridges in Kurdistan Region of Iraq.The outcrops of Pila Spi Formation represent by ridge of carbonate rocks series extended from the NW to the SE North Iraq. It deposited during the Middle-Late Eocene (Khanaqa, 2011; Othman and Al-Qayim, 2010; Jassim, and Goff 2006; Al-Sakry, 1999; and Bellen, Dunnington, Wetzel, and Morton, 1959).It was firstly described by (Less, 1936) in the Pila Spi area within the high folded zone and redefined by (Wetzel, 1947) and modified by (Bellen, 1957) in (Bellen et al., 1959).The study area is located at Gully of Zakho which is about (9 km) southwestern Zakho city (Fig. 1 and 2). During the field work of the Bekhair anticline ,it was found that the Pila Spi formationexposed at two limbs of Bekhair anticline and represented by succession of well bedded limestone, dolomitic limestone and marly limestone with thickness about 230 m. The lower contact of the Formation with Euphrates Formation was recognized by the change of limestone lithology from lithified massive limestone with chert nodules to grey color well lithified bedding altered with thin beds of marl/marly limestone and considered as conformable contact.

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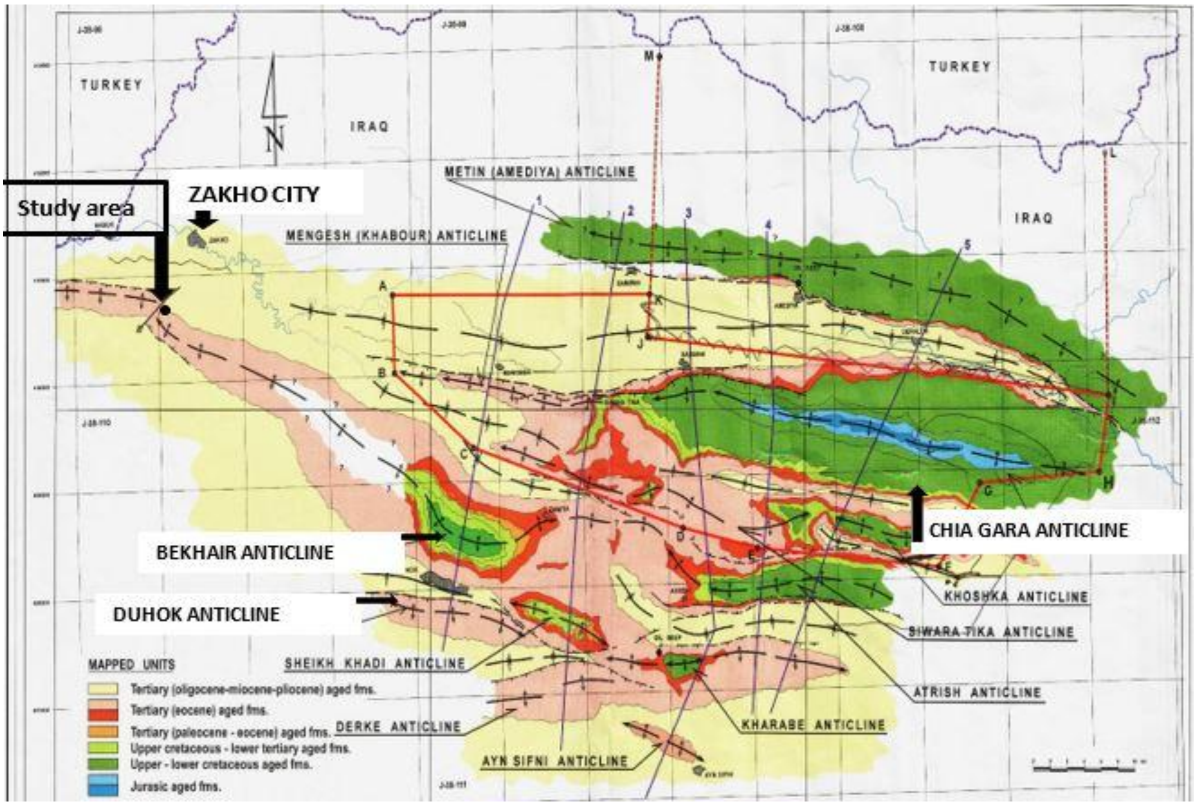

Fig. 1 The regional geological map of northern Iraq shows the anticlines and the study area location after (Merty energy petroleum, 2009).

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Fig. 2: The Studied Section of Pila Spi formation, Bekhair anticline, Gully Zakho.

The carbonates of the Pila Spi Formation represent part of the 'Main Limestone' reservoir of Kirkuk and Bai Hassan oil fields (Bellen 1956). The 'Main Limestone' is a thick, continuous, fractured carbonate sequence of the Pila Spi Formation and the Oligocene Kirkuk Group. Both are sealed by the evaporitic sequence of the Lower Faris Formation. Karstified Pila Spi limestones are known to have reservoir potential from well Chemchamal-2 (Jassim & Buday 2006). The Pila Spi is believed to be one of the reservoirs at the recent Tawke.

The Pila Spi reservoir is characterized by an intricate network of fractures and joints systems. The joints of these rocks are the products of intermittent compression during deposition of the Pila Spi Formation, which become accentuated during the folding of the Zagros fold– thrust belt (Numan at al., 1998). These fractures can be easily recognized in the field. Fractures occur as irregular cracks or uniform sets of joints. In the dolomite unit fractures either filled by secondary calcite cement or remained open, depending on successive calcite cementation. In other less common cases fractures are filled by secondary anhydrite or siliceous cement.
Examination of the Pila Spi Formation from subsurface well data of the Taq oil field in northern Iraq, using core and cutting samples and log analysis supported by outcrop cross-examination, revealed important points about the reservoir potential of this Formation. Dolomitization and leaching enhance the secondary porosity of moldic, vuggy and inter-crystalline pore spaces of the fine crystalline dolostone. Most dolomite type seems to have developed during the early diagenetic stage. Fracturing as a part of the secondary porosity significantly enhances reservoir permeability. Predicted porosity values in most of the units' range between 5 and 20%, with generally good porosity, which renders the reservoir its good quality (Basim Al-Qayim and Divan Othman, 2012).

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II. METHOD OF WORK

This work is achieved through field observation and laboratory work (porosity measures). Extensive field work was done in the Bekhair anticline (Gully Zakho) in order to study general geology characteristics and choose the appropriate sections of Pila Spi Limestone for sampling and description, samples were carefully collected from the several sections of Pila Spi limestone in order to make sure that the samples are ideal representing of this studied section.
There are many methods of measuring the porosity (mercury porosimetry, helium porosimetry, buoyancy, and fluid saturation). In this work the saturation method was used. Since effective porosity is the porosity value of interest to the petroleum engineer, particular attention should be paid to the methods used to determine porosity. For example, if the porosity of a rock sample was determined by saturating the rock sample 100% with a fluid of known density and then determining, by weighing, the increased weight due to the saturating fluid, this would yield an effective porosity measurement because the saturating fluid could enter only the interconnected pore spaces (Tarek,2006).
The saturation method is used to measure the porosity of the rock, firstly, by removing the weathered parts, cleaning and drying the rock, then weighingit in its dry state to give the dry weight. Afterward,the rock is fully saturated and weighed then the bulk volume of the rock is calculated.

III. POROSITY MEASUREMENT

Porosity is defined as a measure of the capacity of reservoir rocks to contain or store fluids. The fluids stored in the pore spaces within the reservoir rocks could be gas, oil, and water. The high porosity values indicate high capacities of the reservoir rocks to contain these fluids.

A great many methods have been developed for determining porosity, mainly of consolidated rocks having intergranular porosity (encountered in oil reservoir). From the definition of porosity, it is obvious that common to all methods is the need to determine two of three volumes: total or bulk volume of the sample, its pore volume, and/or the volume of its solid matrix. The various methods based on such volume determination, called "direct methods", differ from each other in the way these volumes are determined. Other methods are available, called "indirect methods" based on the measurement of some properties of the void space. Examples of such properties are the electrical conductivity of electrically conducting fluid filling the void space of the sample, or the absorption of radioactive particles by a fluid filling the void space of the sample. The porosity of the larger portion of rock is determined statistically from the results obtained on numerous small samples.
Reservoir is a body of rock that has pores to contain oil and gas, and sufficient permeability to allow fluid migration. In order to have a hydrocarbon, there must be a body of rock having sufficient porosity (Φ) to contain the reservoir fluids and permeability (k) to permit their movement, the rocks must contain hydrocarbons in commercial quantities, and there must be some natural driving force within the reservoir, usually gas or water, to allow the fluids to move to the surface.
Porosity of a rock is the fraction of the volume of space between the solid particles of the rock to the total rock volume. The space includes all pores, cracks and vugs. The porosity is conventionally given the symbol(ϕ), and is expressed either as a fraction varying between 0 and 1, or a percentage varying between 0% and 100%.Permeability and porosity of a rock are interrelated as higher porosity implies higher permeability (Sadeq and Yusoff, 2015).
The measurement of porosity is important to the petroleum engineer since the porosity determines the storage capacity of the reservoir for oil and gas. The understanding of petrophysical and multiphase flow properties is essential for the assessment and exploitation of hydrocarbon reserves; these properties in turn are dependent on the geometric and connectivity properties of the pore space. It is necessary to distinguish between the types of porosity because in porous rocks there will always be a number of blind or unconnected pores.
Absolute Porosity is the ratio between the total pore volume (interconnected pores and isolated ones) and the bulk volume of material (i.e., the ratio of the entire pore space in a rock to its bulk volume).The absolute porosity is generally expressed mathematically by the following relationship:

$$\text{Porosity} = \frac{pore\ volume}{bulk\ volume} * 100\%$$

The pre-diagenesis porosity is affected by three major microstructural parameters. These are grain size, grain packing, particle shape, and the distribution of grain sizes. However, the initial porosity is rarely that found in real rocks, as these have subsequently been affected by secondary controls on porosity such as compaction and geochemical diagenetic processes.

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primary porosity is described as the porosity of the rock that formed at the time of its deposition, and primary porosity decreases due to compaction and packing of grains. Secondary porosity is developing after deposition of the rock, secondary porosity includes vugular spaces in carbonate rocks created by the chemical process of leaching, or fracture spaces formed in fractured reservoirs. (Nolansnyder and Parnell, 2019) described the case when they made a comparative pore surface area between the primary and secondary porosity in sandstone (Fig. 3).

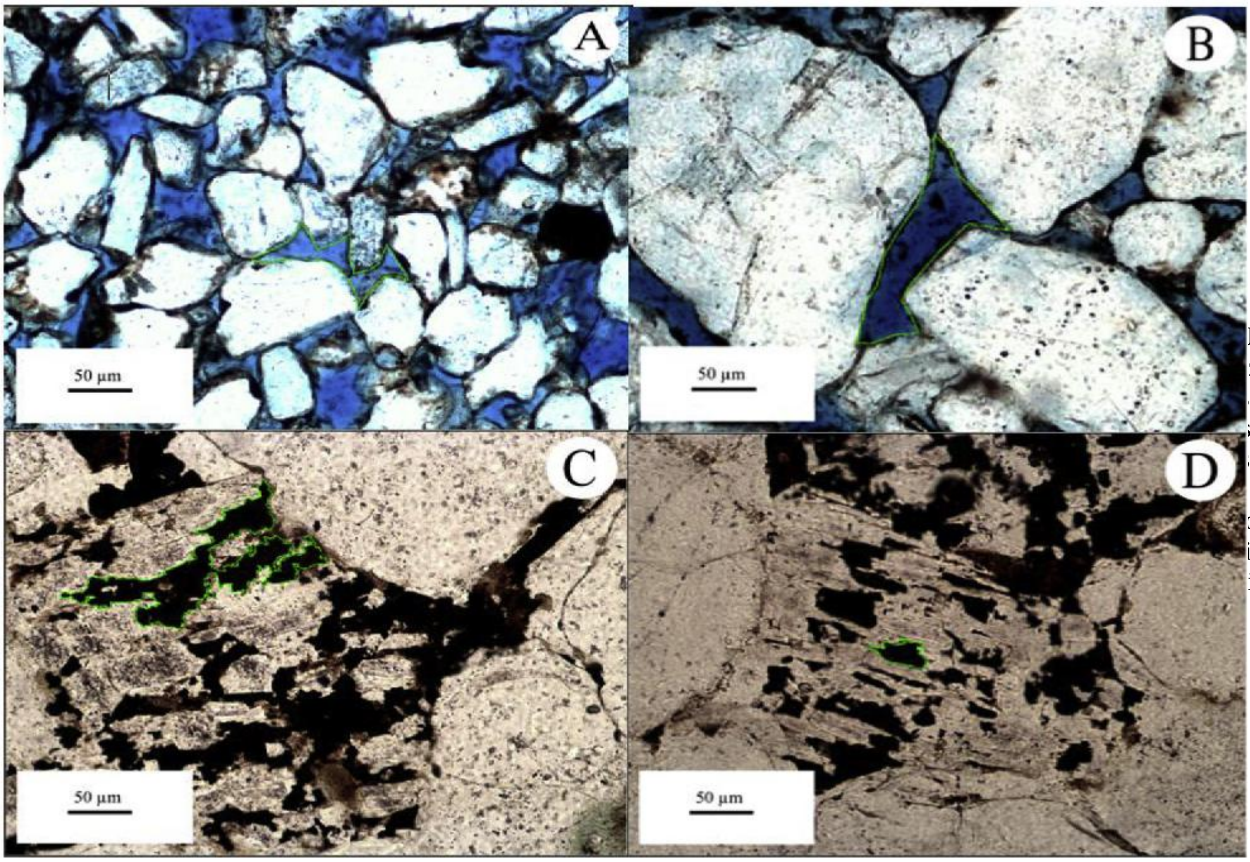

Fig. 3 The primary and secondary porosity in sandstone. A and B are primary porosity, C and D are secondary porosity after (Nolansnyder and Parnell, 2019).

IV. CALCULATIONS AND DISCUSSION

About 21 samples of lime stones were collected from Pila Spi formation. Because Porosity is the ratio of the pore volume to the bulk volume of the reservoir rock in percentage basis, so its formula for determination will be:

$$\text{Porosity} = \frac{pore\ volume}{bulk\ volume} * 100\%$$

$$\text{Porosity} = \frac{bulk\ volume - grain\ volume}{bulk\ volume} * 100$$

$$\rho = \frac{mass}{volume}$$

$$\text{Porosity} = \frac{pore\ volume}{bulk\ volume} = \frac{Vbulk - Vmatrix}{Vbulk} = \frac{Vbulk - {}^{Wdry}/_{\rho matrix}}{Vbulk}$$

$$porosity = \frac{Vpore}{Vbulk} = \frac{Vbulk - Vmatrix}{Vbulk} = \frac{(Wsat - Wdry)/\rho f}{Vbulk}$$

Where;

V pore; volume of the pores.

V bulk; bulk volume.

V matrix; volume of matrix.

Pf; fluid density

And after measuring the parameters above for each sample, the values of porosity were calculated and set out in the (Table 1) below:

Table 1. The porosity ranges in Pila Spi limestone in the study area

No. of samples	Area Section (cm^2)	porosity %
1	1	14.3
2	1	16.0
3	1	14.9
4	1	15.3
5	1	17.7
6	1	17.0
7	1	13.2
8	2	14.5
9	2	16.8
10	3	17.0
11	2	14.0
12	2	15.3
13	2	19.4
14	2	18.2
15	3	15.1
16	3	16.0
17	3	14.8
18	3	12.6
19	3	16.3
20	3	17.9
21	3	13.7

The porosity values of limestone range between (0 – 20 %) according to (Freeze and Cherry, 1979).And according to the results of these analyses, the porosity of Pila Spi limestone formationat Zakho section changes from 12.6% and 19.4%, with an average rate of 15.7%. The changes in the porosity values may indicate the difference in the degree of dolomitization from place to another place, many other factors may incorporate in this change.

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However, the results shown in the table are revealing as good porosity, and had been enhanced by some diagenetic processes, especially dolomitization and dissolution, and later followed by secondary effects from tectonics activities.

V. CONCLUSION

The Pila Spi Formation represents by ridge of carbonate rocks extended from the NW to the SE North Iraq with an age range from Middle Eocene to Late Eocene. The porosity results of the Pila Spi formation indicating dolomitization and leaching enhance the secondary porosity of moldic, vuggy and inter-crystalline pore spaces of the fine crystalline dolostone. Most dolomite type seems to have developed during the early diagenetic stage. Fracturing as a part of the secondary porosity significantly enhances reservoir permeability, and one of the most important one is porosity, which can be used to calculate the total hydrocarbon volume present in the reservoir. Hydrocarbon volume in the reservoir equals pore volume, and to determine porosity accurately we should have a good understanding of pore types due to engineering point view and geological point view. Nowadays porosity can be increased by enlarging the pores, using the chemicals and fracturing the rock enhancing the oil recovery and when the pores are enlarged the permeability will increase too and it will affect the flow rate and production rate of each well in that reservoir. The porosity calculated from 21 samples revealed that the Pila Spi limestone formation has a good porosity with an average of 15.7 % that making it as a good reservoir. It is believed that Pila Spi formation had been dolomitized and affected by tectonism after its solidification which led to increase the ratio of porosity.

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